Chapter 6
Pumping Conditions

6-1. General

This chapter includes the procedures used for determining the pumping conditions. Several different pumping conditions can occur for the same station layout due to multiple hydrology requirements. The determination of pumping conditions for the final station layout should be included as part of the design documents.

6-2. Capacity Determination

The capacity for the pumping conditions is determined from the hydrology requirements. Generally, the stormwater pumps in a station should have equal capacity; however, certain other conditions such as foundation, submergence, inflow requirements, and pump-drive match may dictate the need for pumps of different capacity ratings. Varying the size of the pumps may also be required to minimize pump cycling where ponding storage is small compared with the base flows that must be pumped. Generally, there is a different capacity requirement for low and high river conditions. Intermediate conditions are possible, and also special requirements such as siphon priming may occur. The capacity required for a self-priming siphon discharge is that capacity that provides a velocity of 2.2 meters per second (7 feet per second) in the discharge pipe at the crest of the protection. This value is conservative, and for large stations, a model test of the siphon discharge should be considered to determine the minimum priming velocity. A decrease in this velocity could affect the pump selection. Also, a siphon system that is long or contains many dips should be model tested as the 2.2-meters-per-second (7-feet-per-second) velocity criterion may not prime the siphon. For stations that have a baseflow pumping condition, a separate smaller pumping unit or units are provided to handle the baseflow. The source for the capacity determination should be indicated in the design memorandum.

6-3. Head Determination

a. General. The term used to specify the amount of lift that a pump must overcome when pumping is called total head. Total head is composed of static head, losses in that pumping circuit, and the velocity head developed. All the losses in the portion of the pump that is supplied by the pump manufacturer (generally between the suction bell or flange and the discharge flange or the end of the

elbow) are considered internal pump losses and are not included in any head loss determination included with the pumping equipment specification. In those cases where the suction and discharge systems are complicated and form an integral part of the pump, a model test to determine the total head should be conducted by the Waterways Experiment Station (WES), Vicksburg, MS.

b. Static head. In most flood-control pumping station applications, the static head can be considered the difference between the pool elevation on the inside of the protective works and the pool elevation at the discharge point. Usually there are several different static head requirements for a given station layout or set of hydrology conditions. Consideration should be given to the differences in static head caused by the variation in pumping levels on the intake side between the project authorized level of protection and the minimum pumping level. The static head for satisfying the hydrology requirements is determined from many different sump elevations. These include the minimum pumping elevation, the pump starting elevation, and the average sump elevation. These elevations should be determined during the hydraulic/hydrologic studies. The lowest stopping elevation along with the highest elevation to be pumped against (this elevation is determined according to the type of discharge system being used or the maximum elevation of the discharge pool) is used to determine the maximum static head that will be used to select the pumping unit. A reduction in capacity for this maximum head condition is permitted and should be coordinated with the H&H engineers. If the discharge is to operate as a self-priming siphon, the static head is the difference between the top of the discharge pipe at its highest point and the pump's lowest starting level. For the priming phase of a siphon system and for a vented nonsiphon system, it is assumed that discharge flows by gravity past the highest point in the discharge line, except as noted hereafter. Discharge systems having long lengths of pipe beyond the crest of the levee may have a head profile greater than the top of the pipe at the top of the levee. Typical static head conditions for various types of stations is illustrated on Plates 2-8.

c. Losses.

(1) General. The losses consist of friction and other head losses in the conveying works, before the pump (intake losses), and after the pump discharge (discharge losses). Intake losses include trashrack, entrance gates, entrance piping losses, and any losses in intake channels. Discharge losses include discharge pipes, discharge chamber losses, and backflow preventer valves. These

losses should be considered for different numbers of pumps operating. Generally, the losses will be lowest with one pump operating and highest with all of the pumps in operation. For the majority of pumping stations, the entrance losses, except the loss across the trashrack, will be minor, and in most cases can be neglected.

(2) External losses. These losses start at the station forebay or sump entrance. This is usually the sewer or ditch adjacent to the station. The losses would be from this point to the sump where pump suction occurs. The losses are calculated by applying "K" factors to the various elements of flow and then multiplying them by the velocity head occurring at that location. Based on observations at operating stations, the losses through the trashrack are usually assumed to be 150 millimeters (6 inches). The other losses are those occurring on the exit side of the pump piping and could include the losses occurring in the discharge chamber and its piping system to the point of termination as identified in the hydrology report. The losses in the discharge chamber and piping entrances, exits, and bends are calculated with "K" factors similar to those on the entrance side. A special case occurs in narrow discharge chambers where a critical depth of flow may occur causing the water level in the chamber to be higher than that occurring downstream of the chamber. This usually occurs only for the low head condition. Appendix E provides design information for handling this case.

(3) Pump piping losses. These losses will include all losses in the connecting pipes to the pump including both the entrance and exit losses of this piping. The Darcy-Weisbach formula should be used for determination of piping friction losses. An explanation of the formula and terms used is shown in Appendix E. Methods and factors to be used in determining losses in fittings, bends, entrance, and exits are shown in Appendix E.

d. Velocity head. The velocity head represents the kinetic energy of a unit weight of liquid moving with velocity V and is normally represented as the difference of the kinetic energy of the suction and discharge piping. However, when the pump does not have any suction piping and is fitted with a suction bell, the velocity head is that calculated for the discharge pipe. The velocity head is considered a loss for free discharges and partially or totally recovered for submerged discharges. For the purposes of determination of system losses, and as a safety margin, the entire velocity head will be considered unrecoverable and thereby added to the other losses.

e. Total system head curves. A total system head curve is a curve that includes all the losses plus the static head in the pumping circuit plotted against the pumped capacity. The losses would include both the external and pump piping losses plus the velocity head. A different total system head curve occurs for each static head condition. In determining the total system head curves, the worst-case condition should be considered when multiple pumps of equal rating are used. In a multi-pump station, the piping system that has the greatest losses would be used to determine the total system curve for the highest head condition, while the piping system with the least losses would be used for the lowest total system head. For pumps discharging into a common manifold, the highest head occurs with the maximum discharge level and all pumps operating. The total system head curves for the final station layout shall be submitted in whatever design document preceeds the P&S.

6-4. Suction Requirements

a. General. The two factors to be considered are the NPSHA, resulting from pump submergence, and the flow conditions in the sump. Successful pump operation is not possible without satisfying the effects of these two influences. NPSH is defined in Chapter 5.

b. Submergence. Submergence is defined as the setting of the impeller eye of the pump with respect to the water surface in the suction sump area. Principal factors involved in the determination of submergence requirements are cavitation limits and the prevention of vortexes in the suction sump. Minimum submergence requirements, based on estimated annual operating hours, are provided in Appendix B. Submergence requirements, with respect to the inlet of the pump, to prevent the formation of vortexes in the sump are presented in ETL 1110-2-313 and Appendix B, Chart B-2. The information provided above could yield more than one submergence requirement. However, the most conservative (largest) value of pump submergence should be selected. It must also be remembered that the impeller must be submerged at the start of pumping if the pump is to be self-priming.

c. Flow conditions. The layout of the station, the sump water levels, and the shape of the pump intake determine what flow paths occur in the sump. These flow paths can cause uneven distribution into the pump, which affects pump performance. The most observable detriments of these are vortexes. Certain dimensions that have been found by model testing should be used for

layout of the station. These dimensions are shown in Appendix B and are usable for all stations in which the upstream approach in front of the station is straight for a distance greater than five times the width of the pumping station. Stations with a sharp bend close to the station should be provided with a formed suction intake. The WES Hydraulics Laboratory personnel should be consulted concerning the station's layout and design. WES may be able to apply lessons learned from previous model tests to make design or layout recommendations to avoid possible future operational problems. However, if an unusual entrance condition exists, a model test of the station may be required.

6-5. Pump Requirements

After analysis of the application is made in accordance with Appendix B and the pump operating conditions defined, a pump may be selected to satisfy the design conditions. A suggested data sheet containing information to be forwarded to pump manufacturers is shown on Chart B-3, Appendix B. Selections may be made by the designer from pump catalogs, but it is usually best to confirm this selection with the manufacturers. A selection by a minimum of two manufacturers should be obtained. In some instances, the selection by the manufacturer may be different enough that the station layout may require a change. Before making these changes, an attempt should be made to determine why the manufacturer's selection differs from that selected by the designer. The designer and the pump manufacturer should discuss the basis of the selection. Some differences, such as the next larger sized pump or the next faster or slower driver speed, are probably acceptable since the pump manufacturer may not have an equivalent to the one selected by the designer. In other cases where the pump manufacturer recommends a different type of pump, such as a horizontal pump where a vertical pump was proposed, the change should be evaluated. The studies and pump selections made in accordance with this manual are not made to pick a specific model pump, but to show the design, the type of pump to use for station layout, and to provide guidance on preparing the pump specifications and the type of pump tests to run.